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PRACTICAL TESTS WITH THE "AUTO CONTROL SLOT"

By G. Lachmann

PART I: LECTURE

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PART I: Lecture

The effect of a slotted wing depends essentially on the fact that a secondary flow branches off from the main flow and passes to the suction side of the profile. It is thus possible to delay the separation greatly and increase the lift.

The practical aspect of the slotted wing is less known in Germany, especially the results obtained during the last three years since the introduction of the "auto control slot." There are still misunderstandings regarding our aims and intentions, so that I hope you will be interested in this brief report regarding the progress of our experiments.

Originally we set out with the idea of making the most of the possible increase in lift, with the aid of the slotted wing, for enlarging the speed range. There are two possible ways of doing this, namely, by lowering the bottom speed limit or landing speed and by raising the maximum speed in connection with the reduction of the wing area and the consequent reduction of the wing drag enabled by the greater lift coefficient.

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*"Praktische Erfahrungen mit dem automatischen Spaltflügel," a paper read before the W.G.L., March 17, 1930. From Z.F.M., August 28, 1930, pp. 409-418. For "Part II: Discussion," see N.A.C.A., T.M. No. 594.

With the latter principle, we have thus far had only slight success. The reason is that this method can be profitably employed only on airplanes where the other resistances are small, so that any reduction in the profile drag would have a decided effect. In other words, any improvement made in the flight performances by increasing the wing loading can be beneficial only on aerodynamically efficient airplanes, in the ideal case, therefore, on the "flying-wing" type. Any aerodynamically less efficient airplane can not be greatly improved, as regards speed and economy, even by greatly increasing the wing loading. It is hardly necessary to dwell longer on this principle, since it was first brought to great perfection in Germany, though without regard for the landing speed, and was introduced from Germany into airplane construction in all other countries.

The second way, namely, the reduction of the landing speed without affecting the economy and speed of flight has, from the first, given positive results. I believe that this way will be found valuable for seaplanes for which the minimum speed is more important than for landplanes, the landing run of which can be very much shortened by the use of brakes. The accompanying photographs show a modern form of the slotted wing as used on a French seaplane to reduce the landing speed (Figs. 1-2).

It is also contemplated to put slotted wings on airplanes to be catapulted from ships, in order to reduce the necessary acceleration for heavily loaded airplanes, such as single-seat combat planes.

Originally the general adoption of slotted wings was prevented by the following obstacles:

1. General prejudice, especially on the part of pilots;
2. Increased weight, necessitated by the original form of the slotted wing;
3. Complexity of the wing structure, due to the original system of controls.

Prejudice has not yet been entirely overcome, at least in Germany, though it has been possible, by the introduction of the auto control slot, to simplify the construction considerably and even to keep the weight increase of the wings within narrow limits.

We recently installed on a large airplane an auto control slot gear, which did not weigh more than 0.84 kg/m² (0.172 lb./sq.ft.), 0.6 kg/m² (0.123 lb./sq.ft.) being for the auxiliary wing itself and the balance for the fittings and connections. The weight of the auxiliary wing or flap alone was 4.8 kg/m² (0.983 lb./sq.ft.).

The principal of the auto control slot will be considered later. I will simply mention now that the original principle of the lift of large slotted wings has not been entirely discarded, but, as has already been mentioned, no such importance is ascribed to the landing speed of braked landplanes as ten years ago. With the aid of the auto control slot, however, a new landing technique has been developed which will be considered later.

By far the most extensive application of the principle of the slotted wing has been made at the wing tips, where the auxiliary flaps have little or nothing to do with increasing the lift or reducing the landing speed, but serve simply to maintain the damping of the airplane about its longitudinal axis (which it loses in stalled flight) even at very large angles of attack. This is illustrated by Figure 3, which shows the lift curve for a normal wing and also for a slotted wing. The airplane itself flies at an angle of attack very near the maximum. If the airplane, due to some disturbance (e.g., a gust), begins to turn about its longitudinal axis, the angle of attack of the inner wing tip increases, while that of the outer tip decreases. So long as the resulting angle of attack of the inner tip remains under the critical region of the lift curve, all is well, since the lift increment connected with the increased angle of attack damps the rolling motion. If, on the contrary, the maximum angle of attack is exceeded, then any further increase in the angle of attack causes a decrease in the lift or, in other words, a negative damping which leads to autorotation which can no longer be damped by conventional ailerons. This is a well-known cause of numerous crashes due to stalling near the ground ever since the beginning of aviation. With the slotted wing it is now possible, as easily seen from Figure 3, to maintain positive lateral damping, even at the maximum angle of attack attainable with the aid of efficient elevators.

It will be shown later that stability is maintained even when the slotted wing is stalled.

The first use of the slotted wing for aileron control in stalled flight consisted in connecting the aileron with the forward flap in such manner that the slot was opened by the downward deflection of the aileron (Fig. 4). This expedient was never successful, however, for the following reasons.

a) The effect was secondary, i.e., there was no primary stability, because ordinarily both slots remain closed even in stalled flight.

b) The feel of the control was partly overbalanced and partly sluggish.

c) There was a tendency to lose momentum, and the mechanism was too complex.

In 1927 the Handley Page Company first exhibited an auxiliary wing controlled by the wind forces themselves. The device was the result of a long systematic investigation of all the defects which had been observed in the mechanically operated slotted wings.

The construction of the auto control slot gear is based on the following discoveries.

1. The auxiliary wing or flap, in all intermediate stages of the opening process, must always assume such a position with respect to the surrounding air flow that it will afford a positive lift. The resultant air force will then furnish a component in the direction of the chord of the main wing, which can be utilized in various ways for the automatic control of the flap.

2. The beginning of the opening process can be respectively accelerated or retarded by a slight raising of the leading or trailing edge of the flap. In explanation of both phenomena I may add that, with the original controls for the auxiliary flap, it was always found that the slot began to open very easily, and then suddenly developed a very great resistance to the hand lever. A careful investigation of the motion of the flap showed that, during the opening process, there were intermediate stages at which, so to speak, a negative lift was exerted on the flap.

After this defect was eliminated, an air force was produced which had a constant tendency to open the slot. This force was operative even at small angles of attack, when it was still desirable to keep the slot closed. This second defect could be helped by a slight raising of the trailing edge, because the negative pressure on the upper side of the main wing could then communicate with the lower side of the auxiliary wing.

When an auto control slot gear is to be constructed for any given profile, it is necessary to make a series of preliminary wind-tunnel tests. There have been so many "passable" profiles tested, however, that they have resulted in the adoption of certain standard types which enable an approximately accurate design, thus rendering further experimentation unnecessary, except for adding the finishing touches. The best shape and size of the auxiliary wing and the best arrangement with respect to the leading edge of the main wing are first determined. The best chord for the auxiliary wing is 1/8 to 1/6 of the chord of the main wing. After the dimensions of the slot have been fixed, the air force vector acting on the auxiliary wing is then determined (Fig.6). For making these tests, small holes are made at short intervals along the contour of the auxiliary wing and are connected with a manometer. The manometer is of the so-called "multitube" type and enables the simultaneous reading of all the pressures. The pressures are measured with both closed and wide-open slots throughout the whole angle-of-attack range. Moreover, a pressure measurement is generally made with the trailing edge of the auxiliary wing slightly raised. The measured partial pressures enable the determination of the resultant vectors, which are plotted in a polar diagram. From this diagram all the data on the magnitude and direction of the forces required for the design and static computations can be determined. The design of a suitable mechanism on the basis of these data offers no difficulties. There are two typical mechanisms for this purpose, namely the link mechanism and the slide mechanism. Figure 8 shows an example of the link mechanism. Generally there are three pairs of levers provided for operating the auxiliary wing and these are connected with one another by a torsional equalization shaft, in order to insure uniform opening of the slot.

Figure 9 shows an example of the slide mechanism. The use of a straight guide rail allowed a too sudden opening or closing of the slot. This objection was obviated by using a bent rail, which also offered less resistance and presented a better appearance. This device also eliminated all external fittings and levers.

The question as to whether the auto control slot meets the requirements of lateral stability in stalled flight, may now be considered as answered, since it has been installed on a large number of airplanes in widely separated countries. It is noteworthy and surprising that the lateral damping still holds for angles of attack at which the normal slotted wing already burbles. This fact was first observed in autorotation tests in wind tunnels. The experimental results are given in the British report, R.& M. No. 929. It was found that a wing provided with slots at the tips has a positive lateral damping up to 40° angle of attack and values of $u/v \approx 0.1$. On the contrary, slots running clear through behave like normal profiles, i.e., they fall into autorotation immediately after the beginning of the separation of the boundary layer. I have found this behavior of wings provided with slots near their tips, as observed in the wind tunnel, also confirmed in practice. During the past year I made a series of test flights in Japan with a "Moth" airplane, which was equipped with Handley Page slotted wings. In these flights I determined the direction and magnitude of the velocity vector in all phases of stalled flight with a special instrument, invented by Professor Tamaru of Tokyo, which he graciously placed at my disposal for the test flights. This instrument consists essentially of a small brass cylinder of about 22 mm (0.87 in.) diameter, which has three rows of small holes (Fig. 10). These are connected separately with pressure recorders. From the recorded pressures the velocity and angle of attack can be easily determined. The instrument was mounted far enough from the wing to avoid the effect of the circulation. A rough calculation shows that the circulation about the wing does not differ from the measured angle of attack by more than $+1^\circ$.* Figure 11 shows a record, made by this instrument, of a so-called "superstall." It shows that an angle of attack of about 37° could be maintained for about half a minute. The shortness of the time was due simply to the small circumference of the recording drum and to the altitude, as the sinking speed was considerable. This flight was made in very gusty weather. The airplane was a standard "Moth" with a Cirrus Mark II engine; pilot, Dr. Lachmann; observer, T. Fujimoto. Aviation field, Tachikawa near Tokyo. Date, April 23, 1929.

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*The calculation is made according to the following formulas:

$$\rho v^2 = C \sqrt{2 (P_2 - P_1)^2 + 0.95 (P_2 + P_1)^2}$$

and

$$\theta = 0.414 \tan^{-1} \frac{0.689 (P_2 + P_1)}{(P_2 - P_1)}$$

in which

$P_1 = (P_A - P_B)$ $P_A u P_B$ = pressure at A and B

$P_2 = (P_B - P_C)$ $P_B u P_C$ = pressure at B and C

C = Constant = ~ 1.

After we had succeeded in satisfactorily maintaining lateral stability in stalled flight with the aid of the auto control slot, the next step was to improve the action of the ailerons and the lateral control at large angles of attack.

This was important, especially for the use of the auto control slot in military and stunt flying, where it is desired to profit by the reduction of the natural lateral damping on the conventional profile in the performance of certain stunts, such as the flat spin or stalled turn. This stunt is naturally impossible with slotted-wing airplanes, for which the lateral damping persists even at large angles of attack.

The ailerons retain an adequate effectiveness on slotted-wing airplanes in stalled flight. The airplane naturally responds more slowly to the controls than at higher flight speeds, and, provided there is no differential action of the ailerons, the adverse moments of yaw make themselves increasingly felt and necessitate the simultaneous use of the rudder.

The obvious thing was to improve the aileron control by the arbitrary regulation of the lateral damping, i.e., by reducing or entirely eliminating the slot effect on the side of the rising aileron. Two devices have given practical results:

a) A device, in which the aileron is so connected with the auxiliary wing that, when the former rises, the slot is reduced or closed;

b) An "interceptor" (or "spoiler") for controlling the slot.

Figure 13 represents the principle of the interceptor. This is so controlled by the aileron that it simply rises and closes the slot when the aileron rises with the slot open. At first glance this device seems very simple and obvious. As a matter of fact, it required a long series of systematic investigations to discover the most effective arrangement and the best transmission ratio between the motions of the interceptor and the aileron. It was found necessary to place the interceptor at the trailing edge of the auxiliary wing (with open slot), which complicated the control mechanism, because, with this arrangement, the auxiliary wing covers the interceptor when the slot is closed, so that, in this position, the motions of the interceptor are automatically eliminated.

Since there is but little lateral leeway for operating the ailerons when the control stick is pulled clear back, it was found necessary to increase greatly the transmission ratio of the interceptor so that it would be fully deflected by only a small deflection of the aileron. The lateral control obtained with the help of the interceptor in stalled flight is so effective and sharp that one is at first inclined to overdo it. The following maneuver is especially impressive. The rudder is strongly deflected in fully stalled flight. The airplane then goes promptly on the inner wing and begins a steep spiral. Through the slight yielding of the aileron, which is connected with the interceptor on the outer wing tip, there is an instantaneous damping and return to the normal attitude, even though the rudder remains deflected.

Figures 11 - 16 show a general comparison of the three systems,

a) Auto control slot,

b) Aileron controlled auxiliary wing or flap,

c) Automatic slot and interceptor,

as regards their efficacy in damping an intentional or unintentional rotation of the airplane about its longitudinal axis. Let the assumed airplane be in the stalled attitude ($\alpha = 20^\circ$) and the angular rotation speed be the same in all three cases, as also the size and deflection of the aileron. At the wing tip t_2 there will accordingly be an angle of attack $\alpha + \delta\alpha$ and at the wing tip t_1 an angle $\alpha - \delta\alpha$. A criterion is thus obtained for the rolling moments by taking the difference between the lift values at the two wing tips. In this way we obtain the line d - h, e.g., as the criterion for the effective rolling moment of an ordinary automatic slotted wing, the line d - g for the aileron controlled auxiliary wing and d - k for the interceptor controlled auto control slot. The same method applied to the drag curves (Fig. 15) yields a criterion for the anticipated moments of yaw.

Lastly, Figure 16 shows the result of the investigation, whereby the airplane-fixed moment vectors were finally obtained from the ones fixed with respect to the air. (The fixed system of airplane axes is thereby assumed to be parallel and perpendicular to the wing chord.)

This comparison shows the superiority of the interceptor-equipped wing over the other two systems, as regards both the rolling and yawing moments, which, moreover, in all three cases turn in the right direction, namely in the same direction as the corresponding rolling moments.

Pilots often hold the opinion that thick profiles do not require any special aid to maintain the lateral damping in stalled flight and that the slotted wing is therefore adapted only for use on thin and medium profiles. As a matter of fact, separation takes place on thick profiles the same as on thin ones, though at somewhat greater angles of attack.

The reason many airplanes seem to preserve their lateral stability in stalled flight is due to the fact that they can not be stalled simply by pulling, either because the horizontal tail surfaces are too small or because the efficiency of the elevator is diminished at the critical angle of attack. This assertion is confirmed by Figure 17, which shows the resultant longitudinal moments for different positions of the stabilizer and elevator on a well-known cantilever monoplane. In all cases the moments are based on the normal C.G. of this type. Figure 17 shows that a maximum angle of attack of $14 - 15^\circ$ can be attained with the maximum incidence of the stabilizer and elevator. The critical angle of attack can be reached only by abnormal trimming and excessive deflection of the elevator. The auto control slot has nothing to do with this paradox, according to which greater safety is attained through diminished controllability. The auto control slot does not make an airplane stallproof, but it enables the execution, maintenance and utilization of stalling, as a safe, continuous flight condition, through the maintenance of the lateral damping and the prevention of unintentional spinning. In this way stalled flight lost the dread, which had clung to it from the beginning of aviation. The idea of a critical minimum speed, the approach to which makes flight dangerous, has hitherto been peculiar to the airplane alone. Of all other vehicles it may be said that the safety is inversely proportional to the speed. The object of the auto control slot is to make this principle applicable to airplanes. The purpose is not therefore to create an artificial speed limit in the subcritical portion of the polar by diminishing the effectiveness of the controls, as in a "stallproof" airplane, but to effect the greatest possible extension of the lower speed limit and to insure the safety of flight in the supercritical portion of the polar.

The practical results of this principle are partly primary, namely the elimination of accidents due to loss of speed and unintentional spins at low altitude, and partly secondary through facilitating the landing of an aerodynamically efficient airplane in a field surrounded by obstacles. A good fineness ratio (L/D) is an advantage for the economy of flight and a disadvantage in landing.

Figure 18 shows the phases of an average landing over an obstacle. Let ϵ represent the fineness ratio. Then

$$S_1 = (H - h') \frac{1}{\epsilon},$$

and for two airplanes, differing simply in their angle of glide, the difference in the total landing distance is

$$\Delta L = (H - h') \left(\frac{1}{\epsilon_1} - \frac{1}{\epsilon_2}\right).$$

Figure 19 shows the reduction in the length of glide and also the reduction in the total landing distance, as made possible by the impairment of the fineness ratio, the assumptions being $\epsilon_1 = \frac{1}{9}$ and h_1' (levelling-off altitude) = 3 m (9.84 ft.).

For heavily loaded and aerodynamically efficient airplanes, the best fineness ratio occurs at large lift coefficients, so that further increase in the angle of attack in the subcritical region of the polar causes no considerable impairment of the angle of glide. The c_a value corresponding to the best fineness ratio results from the condition that the induced drag equals the remaining drag. If we put $c_{w_s} = 0.04$ (coefficient of the remaining drag) for a modern commercial airplane and adopt an aspect ratio of $\lambda = 7$, we obtain from

$$c_{w_i} = \frac{c_a{}^2}{\pi \cdot \lambda} = 0.04$$

the c_a value 0.94 and

$$\left(\frac{c_a}{c_w}\right)_{max} = \frac{0.94}{0.08} = 10.65.$$

Separation of the boundary layer begins between $c_a = 1.2$ and 1.3 on all thick profiles and the lateral damping begins to diminish at that point. Flight is therefore unsafe in this region, if it is possible at all through pulling. This example shows how narrowly restricted is the range of glide with safe lateral stability after the best fineness ratio is exceeded.

If, on the other hand, a wing equipped with stabilizing slots at its tips can retain its lateral stability at angles of attack of 25 to 30°, the profile drag is then immensely increased by the separation of the flow, and gliding angles of 1/4 to 1/3 can be attained, whereby the gliding speed is approximately of the order of magnitude of the minimum speed. Stalling to such a large angle of attack can be effected by gradual throttling and simultaneously gradual pulling, without serious changes in the attitude of the airplane.

Of course it is not generally possible to glide so near the ground, because the sinking speed is too great and there is no reserve lift for levelling off and resuming horizontal flight. The landing must take place as shown in Figure 19. The airplane glides at full stall to the point A. Then the angle of attack is greatly reduced by pushing (and possibly by giving more gas), so that the point B is reached at normal gliding speed which enables the conventional levelling off and continued flight at gradually diminishing speed.

The requisite acceleration altitude and time are easily underestimated. The following example will show how to estimate them.

G = gross weight.

c_w = drag coefficient with the subcritical c_a value and angle of attack corresponding to the fineness ratio ϵ_2.

γ = air density (assumed to be constant).

F = wing area.

v_0 = speed at the beginning of the acceleration at B.

v_1 = speed at normal gliding flight.

g = gravity constant.

The differential equation for the acceleration process is then

$$\frac{G}{g} \cdot \frac{dv}{dt} = G \cdot \epsilon - c_w \cdot F \cdot \frac{\gamma}{2\,g}\, v^2.$$

After introducing the constants $a = \epsilon \cdot g$ and $b = \dfrac{c_w \cdot \gamma}{2\ G/F}$,

the integration yields the following results:

a) Time

$$t = \sqrt{\frac{1}{a.b}} \left[\text{arc tan} \left(v \sqrt{\frac{b}{a}} \right) \right]_{v_0}^{v_1} \tag{1}$$

b) Speed

$$v = \sqrt{\frac{1}{a.b}} \tan (t \sqrt{ab}) \tag{2}$$

c) Length of glide

$$S = \int v \cdot dt = \frac{1}{b} \ln \cos (t \sqrt{ab}) + C \tag{3}$$

and, after the introduction of t from Equation (1) with the consideration that

$$\cos (\text{arc tan } x) = (1 - x^2)^{-\frac{1}{2}},$$

$$S = \frac{1}{b} \ln \sqrt{\frac{1 - v_o^2 \frac{b}{a}}{1 - v_1^2 \frac{b}{a}}} \tag{4}$$

and

$$h = \frac{S}{\sin \mu}, \text{ where } \mu = \text{arc tan } \epsilon_2 \tag{5}$$

<u>Example</u>.- The following data were obtained from flight measurements for a well-known type (commercial monoplane with cantilever wings).

$G/F = 55$ kg/m^2 (not fully loaded).

$c_w = 0.1$.

$v_o = 28$ m/s (estimated).

$v_1 = 36.2$ m/s.

$\epsilon_2 = 1/3$ (estimated).

Results

$t = 4.08$ s (acceleration period).

$s = 1.23$ m (acceleration distance).

$h = 39.1$ (acceleration altitude).

The space and time for this landing process, as shown by the above investigation, are ample and make no special demands on the skill of the pilots. Moreover, underestimation of the acceleration altitude means simply a lengthening of the landing flight, while, in the event of overestimation, the acceleration can be increased by giving more gas. The above calculations have to do with airplanes which are simply provided with stabilizing slots near the wing tips.

When a slot extending throughout the whole span in connection with lift increasing wing flaps is used on airplanes of not excessive wing loading, the sinking speed and the kinetic energy in a steep glide of about 13 - 15° are small enough to be absorbed by oil shock absorbers with lengthened travel of spring.

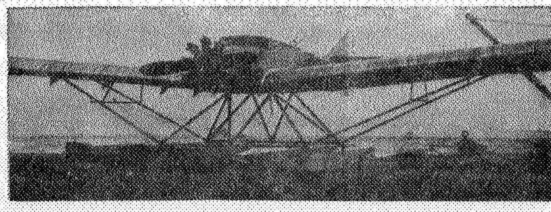
Figure 21 shows the airplane built by the Handley Page Company for the Daniel Guggenheim Safety Contest, which rated only one point below the Curtiss "Tanager," also equipped with an automatic slotted wing. The Handley Page airplane has an automatic wing flap, which is connected with the aileron in such a way that, when it is raised, it depresses the aileron. The principal characteristics and performances of the Handley Page "Gugnunc" are as follows.

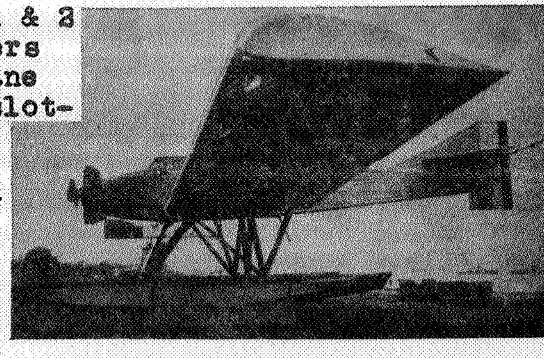
Weight empty	619 kg	(1364.66 lb.)
Load	356 "	(784.84 ")
Weight loaded	975 "	(2149.50 ")
Wing area	27.4 m^2	(294.93 sq.ft.)
"Mongoose" engine	150 hp.	

v_{max}	181 km/h	(112.5 mi./hr.)
v_{min}	54 "	(33.6 ")

The sinking speed in stalled flight with the slot open is only about 4 to 4.5 m/s (13 to 14.8 ft./sec.). Since the landing gear is constructed accordingly, it is possible to descend at full stall from any altitude, a manner of landing which makes practically no demands on the skill of the pilot. "Flying means landing" according to the celebrated dictum of Siegerts. I believe, therefore, that this transformation of landing into a comfortable parachute-like descent and the consequent simplification of flight should enable a more extensive adoption of the airplane as a private vehicle.

Translation by Dwight M. Miner,
National Advisory Committee
for Aeronautics.





Figs.1 & 2 Villiers seaplane with slotted wing (leading-edge flap and slot).

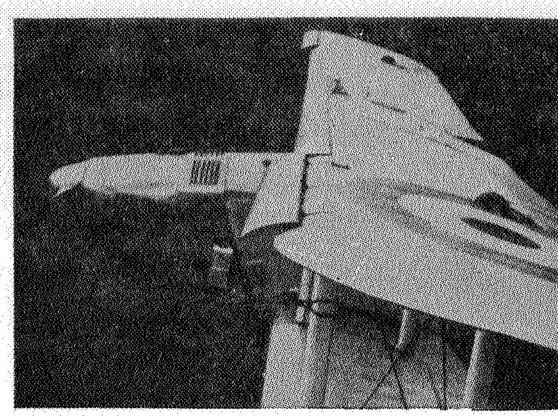


Fig.5 Auto control slot on Handley Page Harrow

Fig.21

The Handley Page "Gugnunc" built for the Daniel Guggenheim safety contest.

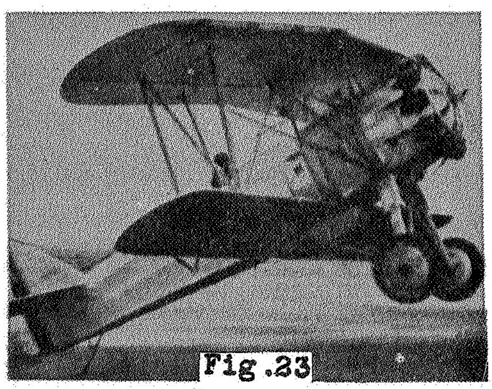


Fig.23

Fig.24

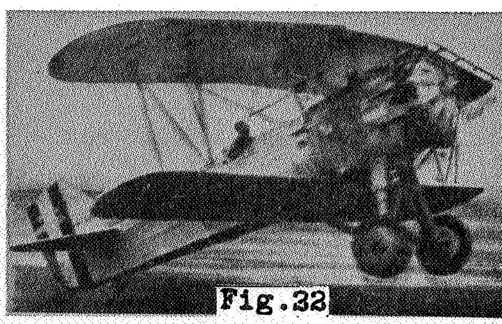


Fig.22

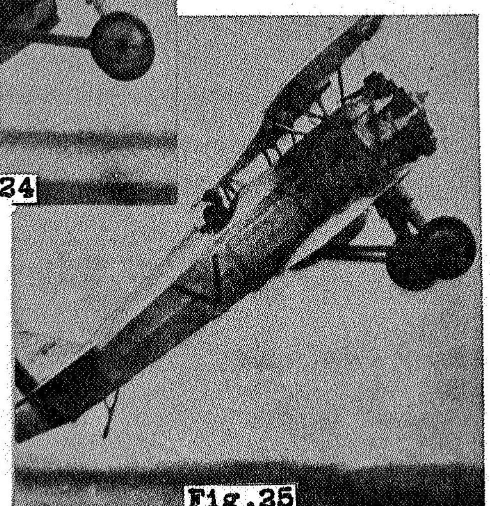


Fig.25

Figs.22,23, 24,25. Successive phases of a stalled start of an American single-seat fighter.

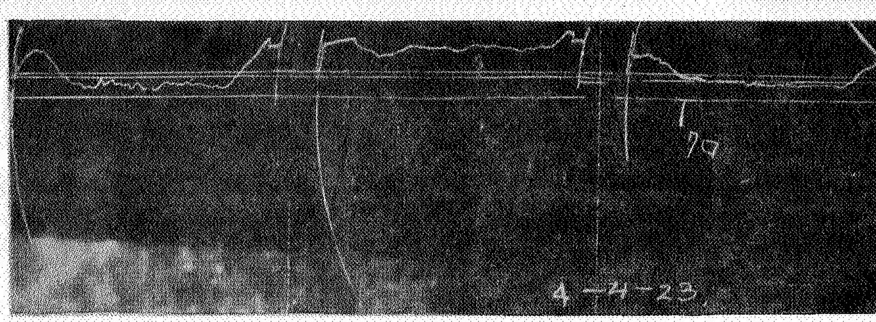


Fig.11 Combined record of the 3 pressure recorders during a test flight. Standard "Moth" with Cirrus Mark II engine. Tachikawa aviation field near Tokyo, Japan.

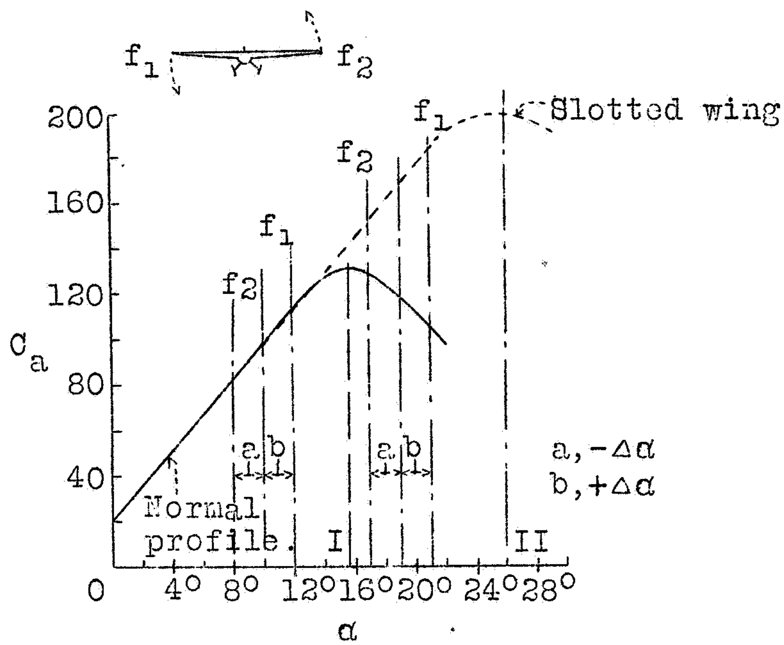


Fig.3 I.Critical angle of attack of the normal wing.
II. " " " " " " slotted " .

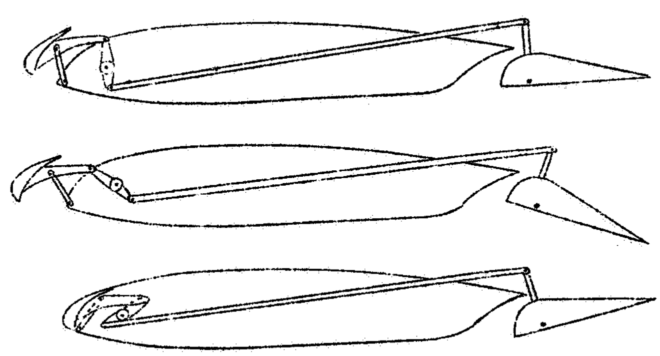


Fig.4 Auxiliary wing controlled by the aileron.

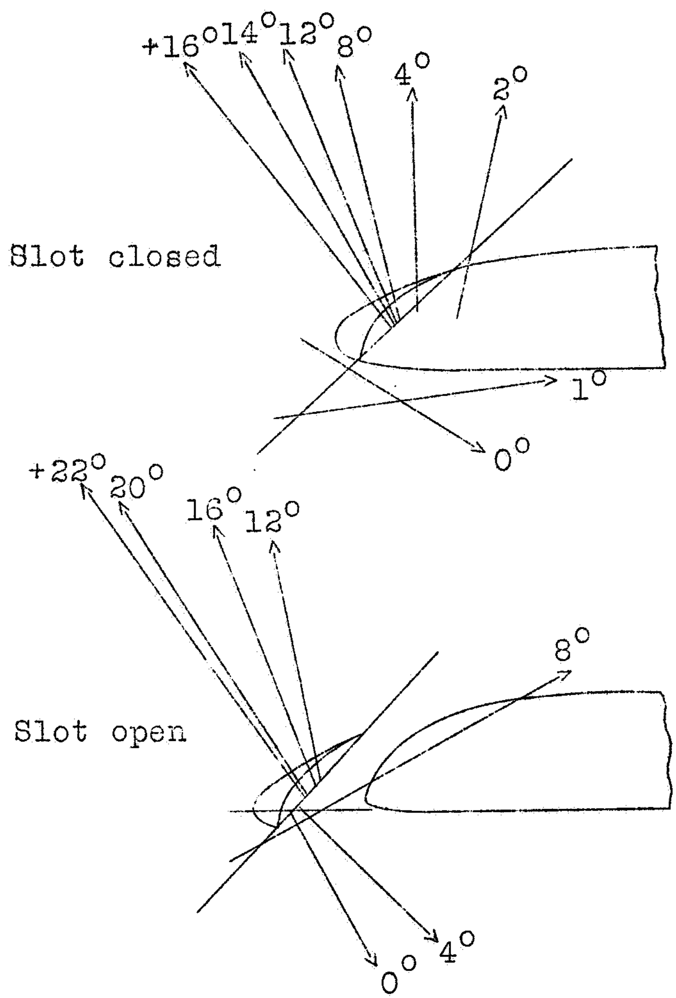


Fig.6 Direction of the resultant air forces on a slotted wing.(The vectors only indicate direction and not magnitude.)

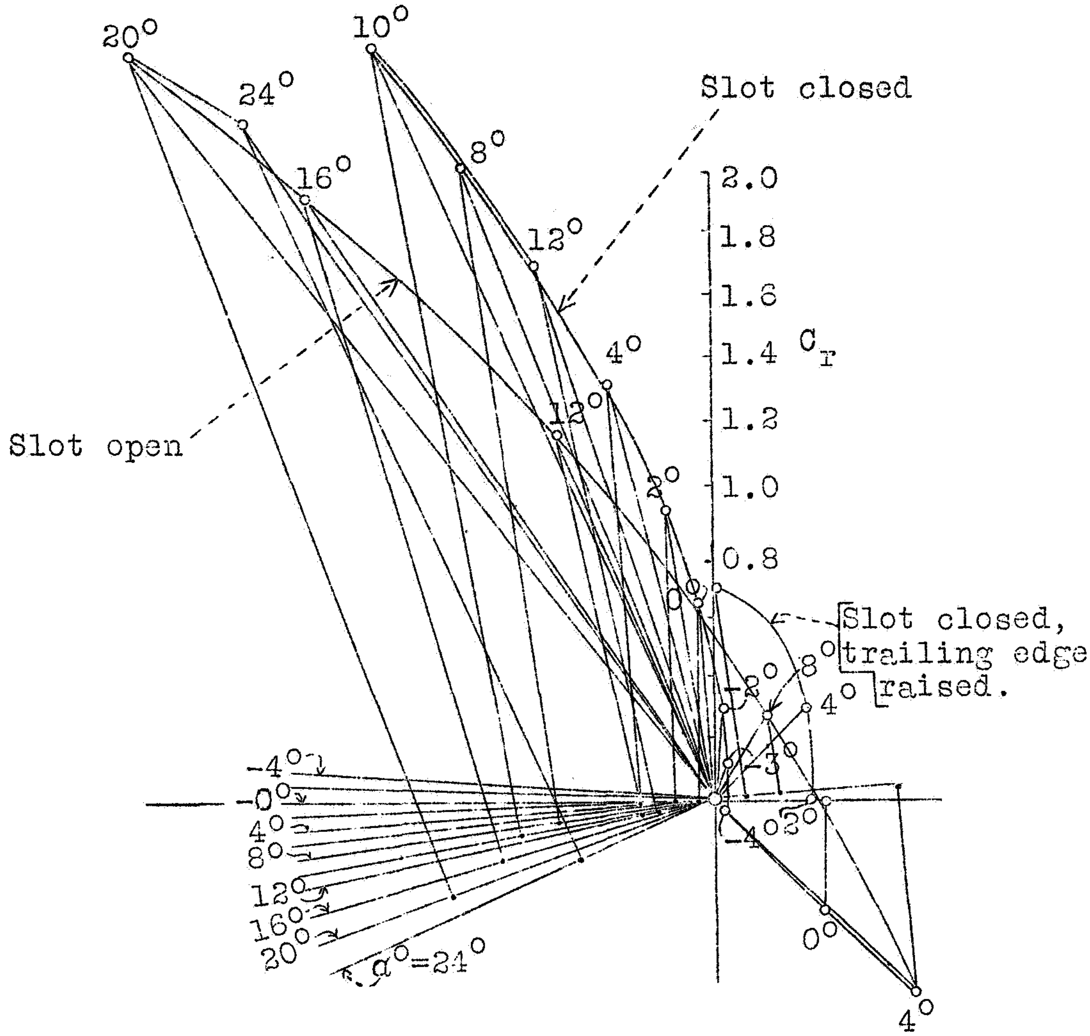


Fig.7 Polar diagram of the resultant air-force vectors on the auxiliary wing with slot open and with it closed(with and without raising the trailing edge of the auxiliary wing.)R.A.F.28 wing section.

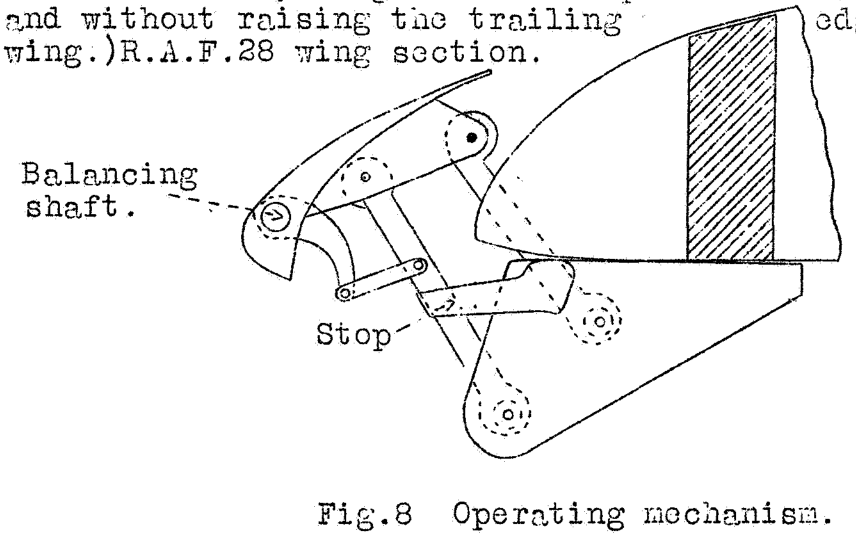


Fig.8 Operating mechanism.

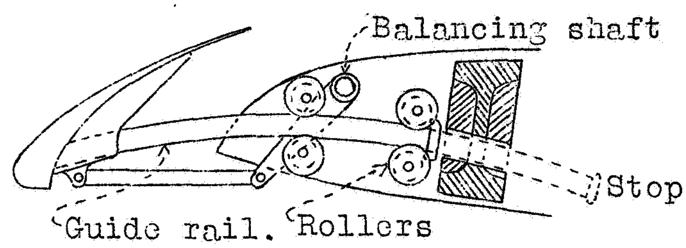


Fig.9 Sliding mechanism

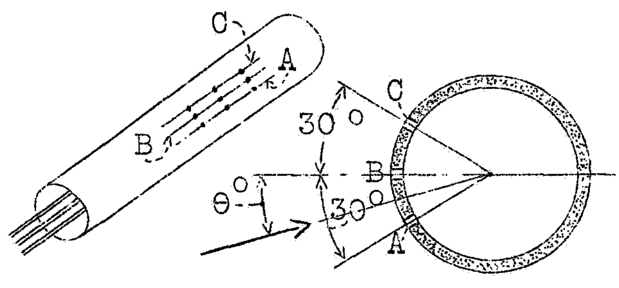


Fig.10 Tamuru's instrument for determining the speed and direction of flight.

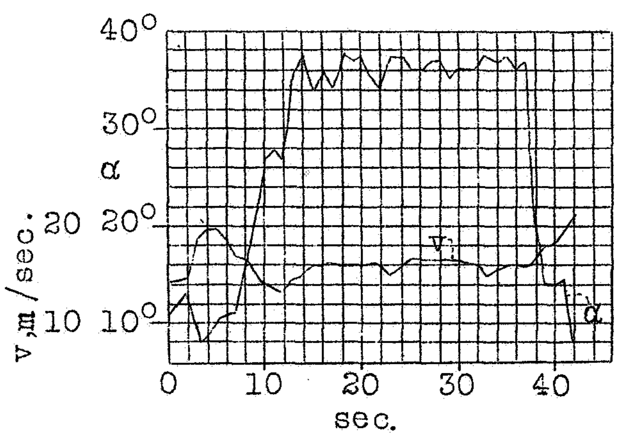


Fig.12 Interpreted record of the speed and angle of attack during a steady stalled glide.

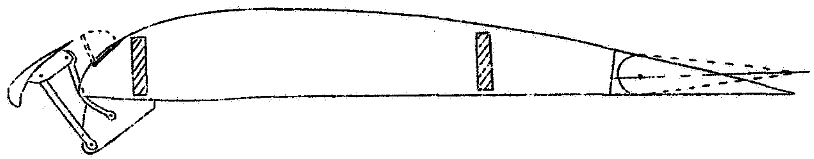
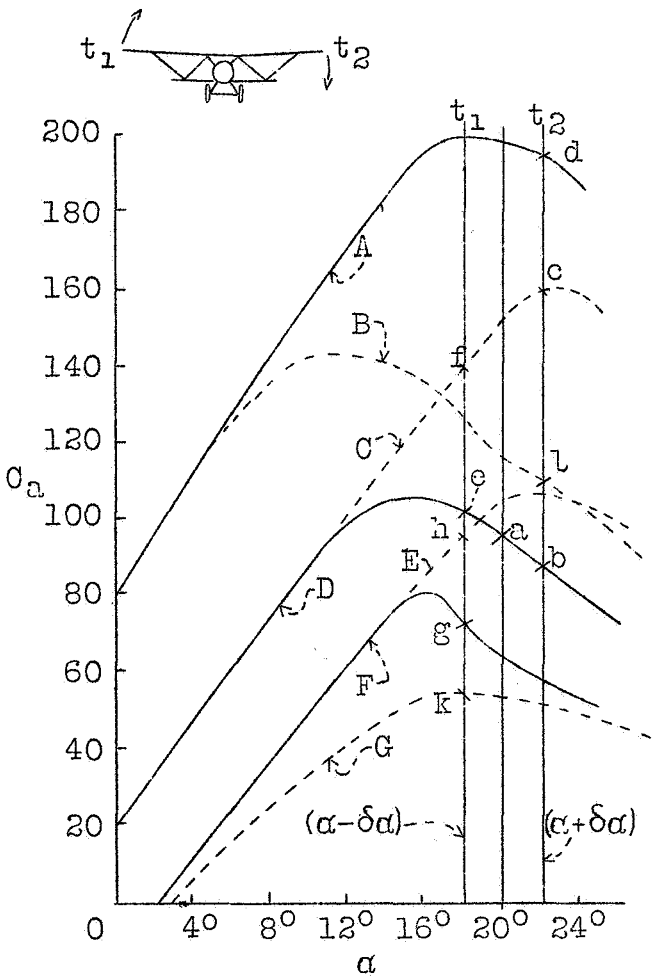
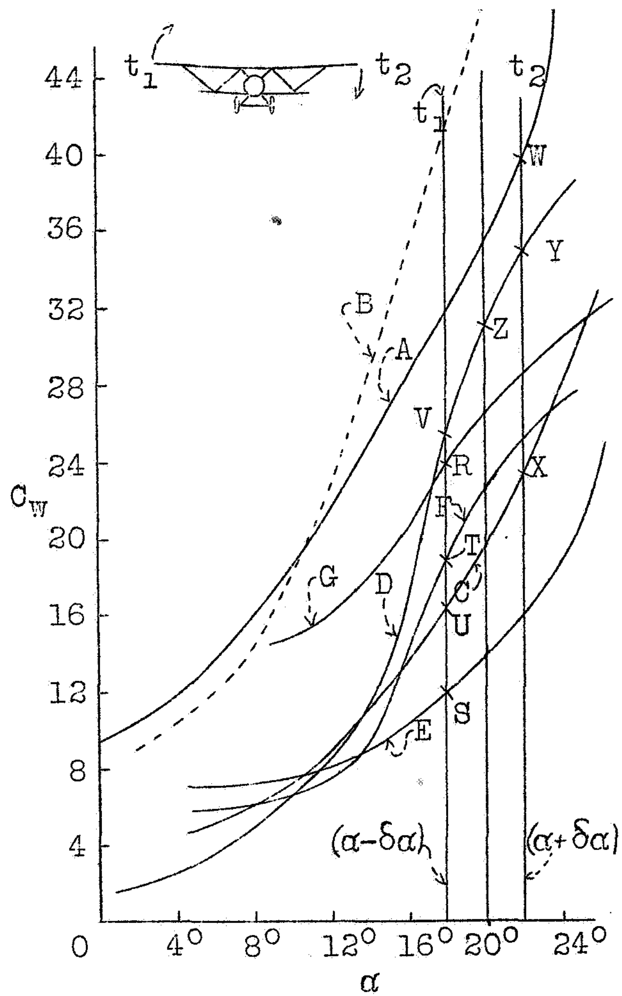


Fig.13 Principle of the aileron-controlled interceptor. Closing the slot automatically eliminates the motion of the interceptor.





A, Slot open, aileron down
B, " closed, " "
C, " Open, " neutral
D, " closed, " "
E, Slot open, aileron up
F, " closed, " "
G, Interceptor in position, aileron up.

Fig.14 Course of the lift coefficients at the wing tips for intentional damping of a rolling motion of the airplane in stalled flight. The curves correspond to the above conditions.

Fig.15 Drag coefficients corresponding to the lift curves in Fig.14 (Notation same as in Fig.14)

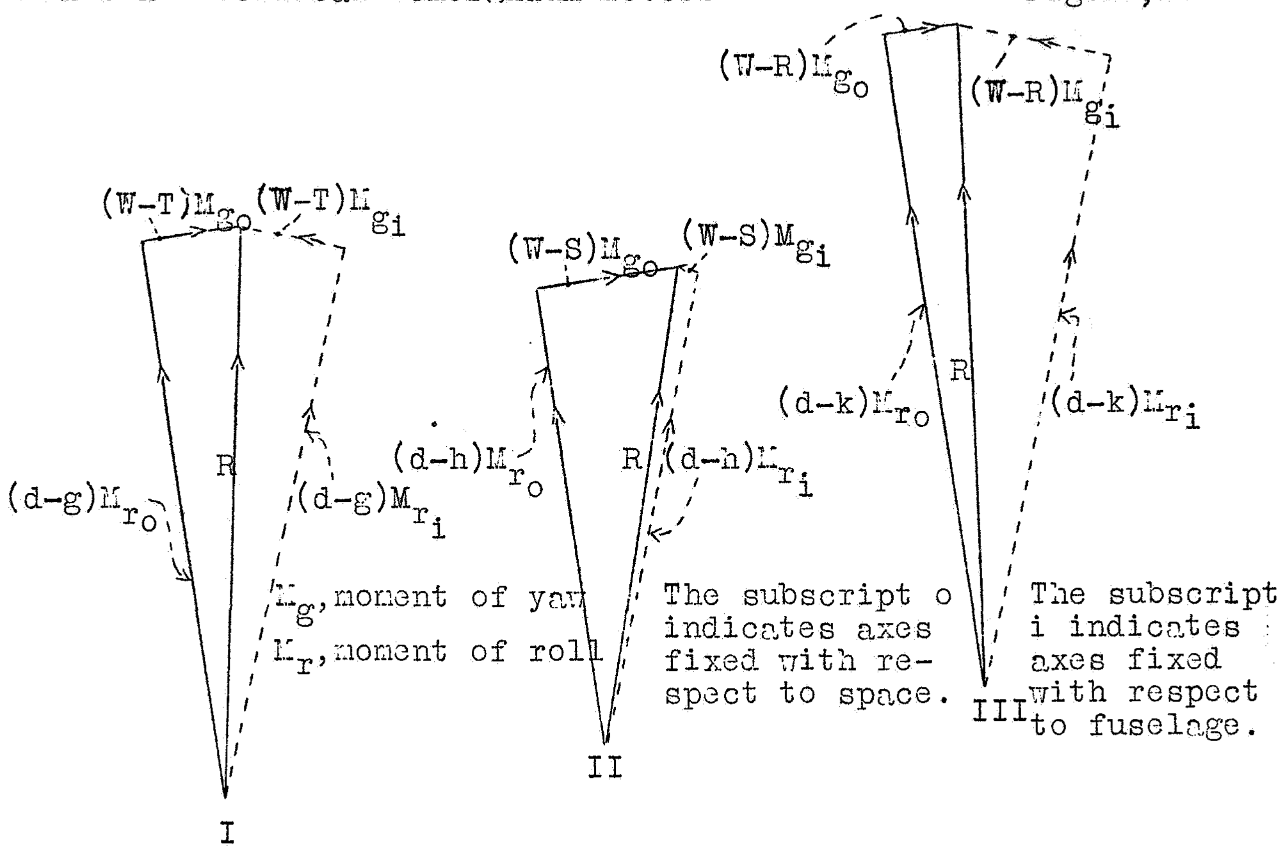
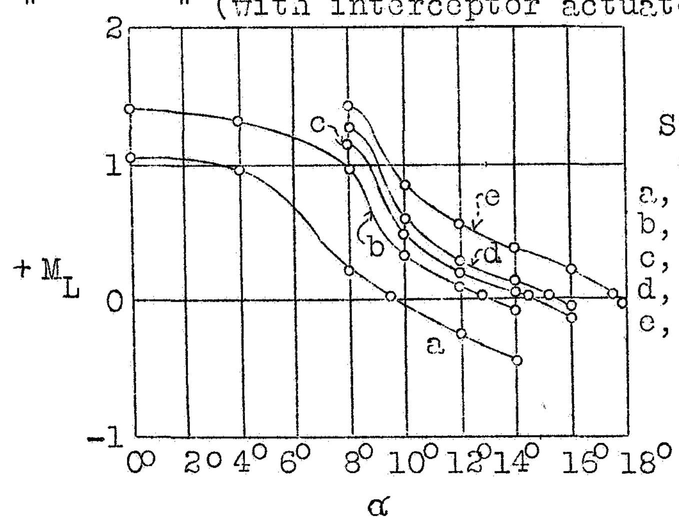


Fig.16 Comparison of resultant moment vectors for three different arrangements.
I. Auxiliary wing controlled by aileron.
II. Auto control slot (not connected with aileron)
III. " " " (with interceptor actuated by aileron.)



	Stabilizer setting	Elevator deflection
a,	-40'	-8°
b,	-40'	-16°
c,	-40'	-25°
d,	-2°	-20°
e,	-6°	-20°

Fig.17 Longitudinal moments determined in the wind tunnel for the model of a well known airplane with cantilever wings at various angles of setting of the stabilizer and elevator.

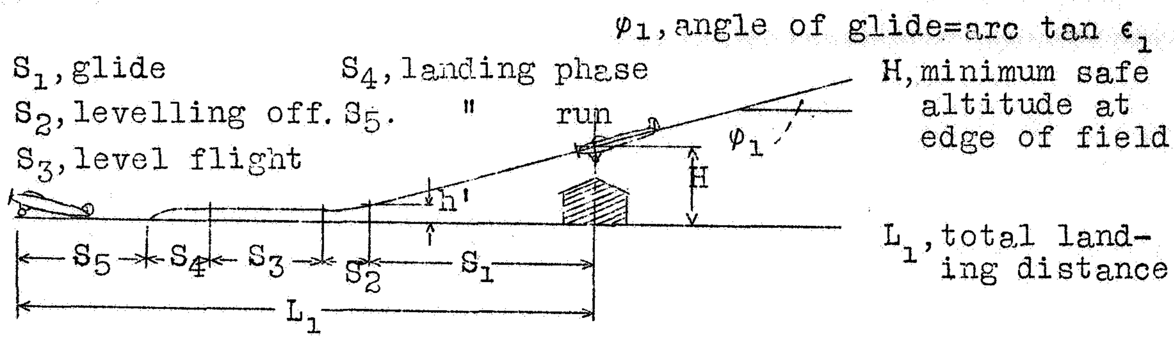


Fig.18 Different phases of a normal landing.

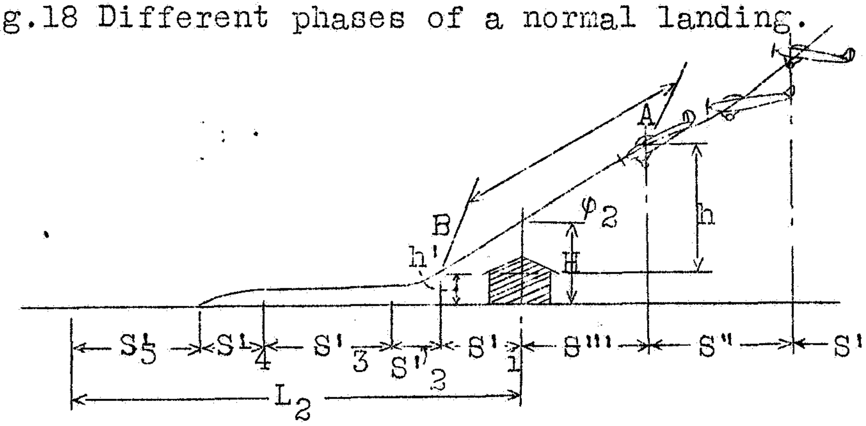


Fig.19 Landing from a stalled glide.

S', stalled glide

S", pushing at small angle of attack

S'''+ S_1', acceleration (compare Fig.18)

h , acceleration altitude

s, " distance.

φ_2, angle of glide.

Fig.19 Landing from a stalled glide.

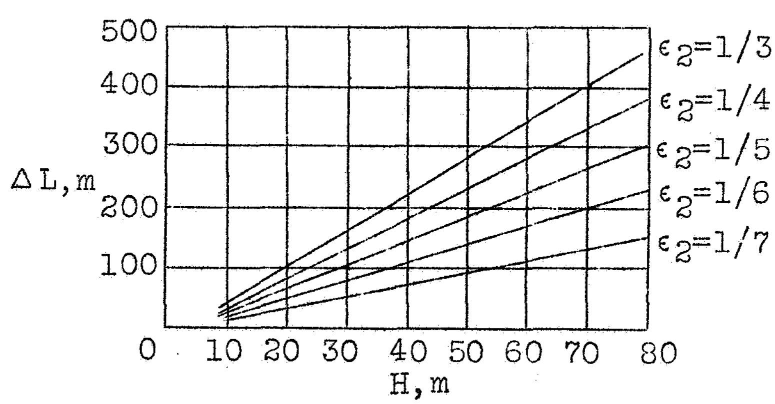


Fig.20 Reductions in total landing distance due to less efficient finess ratios.